ILRS SLR Mission Support Request Form
Retroreflector Information

Satellite name: PROBA-2

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A prerequisite for accurate reduction of laser range observations is a complete set of pre-launch parameters that define the characteristics and location of the LRA on the satellite. The set of parameters should include a general description of the array, including references to any ground-tests that may have been carried out, array manufacturer and whether the array type has been used in previous satellite missions. So the following information is requested:

1. Array type (spherical, hexagonal, planar, etc.), to include a diagram or photograph:
   7 reflectors (1 central and 6 lateral in a circular arrangement) mounted on a flattened cone.
   See picture for further details.

2. Array manufacturer:
   Scientific Research Institute for Precision Instruments, Moscow

3. Link (URL or reference) to any ground-tests that were carried out on the array:

4. The LRA design and/or type of cubes was previously used on the following missions:
   CryoSat-1/2, GOCE

For accurate orbital analysis it is essential that full information is available in order that a model of the 3-dimensional position of the satellite centre of mass may be referred to the location in space at which the laser range measurements are made. To achieve this, the 3-D location of the LRA phase centre must be specified in a satellite fixed reference frame with respect to the satellite's mass centre. In practice this means that the following parameters must be available at mm accuracy or better:

5. The 3-D location (possibly time-dependent) of the satellite's mass centre relative to a satellite-based origin:
   Spacecraft CoM (X,Y,Z) = (-0.0160m,-0.0060m,+0.3810m)

6. The 3-D location of the phase centre of the LRA relative to a satellite-based origin:
   LRA CoM (X,Y,Z) = (+0.2085m,-0.2390m,+0.0102m), LRA MSC (X,Y,Z) = (+0.2085m,-0.2390m,+0.0300m)
   Note: the LRA center-of-mass is offset by 19.8 mm from the reference point (= mounting surface center, MSC) along the boresight of the central reflector. The range finding correction relative to the mounting surface center amounts to +19±6 mm, and depends on the angle of position and the spacecraft bearing relative to station SLR, and shall be added to the measured range.

However, in order to achieve (6) if it is not directly specified (the ideal case) by the satellite manufacturer, and as an independent check, the following information must be supplied prior to launch:

7. The position and orientation of the LRA reference point (LRA mass-centre or marker on LRA assembly) relative to a satellite-based origin:

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8. The position (xyz) of either ~~the vertex~~ or the centre of the front face of each corner cube within the LRA assembly, with respect to the LRA reference point and including information of amount of recession of front faces of cubes: (dX,dY,dZ)_0 = (+0.000m,-0.000m,-0.0480m)
(dX,dY,dZ)_i = (+0.0455*cos(π/3*(i-1)),-0.0455*sin(π/3*(i-1)),-0.0285m), i=1,...,6

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9. The orientation of each cube within the LRA assembly (three angles for each cube):
See design drawing

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10. The shape and size of each corner cube, especially the height:

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11. The material from which the cubes are manufactured (e.g. quartz):
fused silica with aluminium-coated reflecting prism faces

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12. The refractive index of the cube material, as a function of wavelength λ (micron):

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13. Dihedral angle offset(s) and manufacturing tolerance:

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14. Radius of curvature of front surfaces of cubes, if applicable:

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15. Flatness of cubes' surfaces (as a fraction of wavelength):

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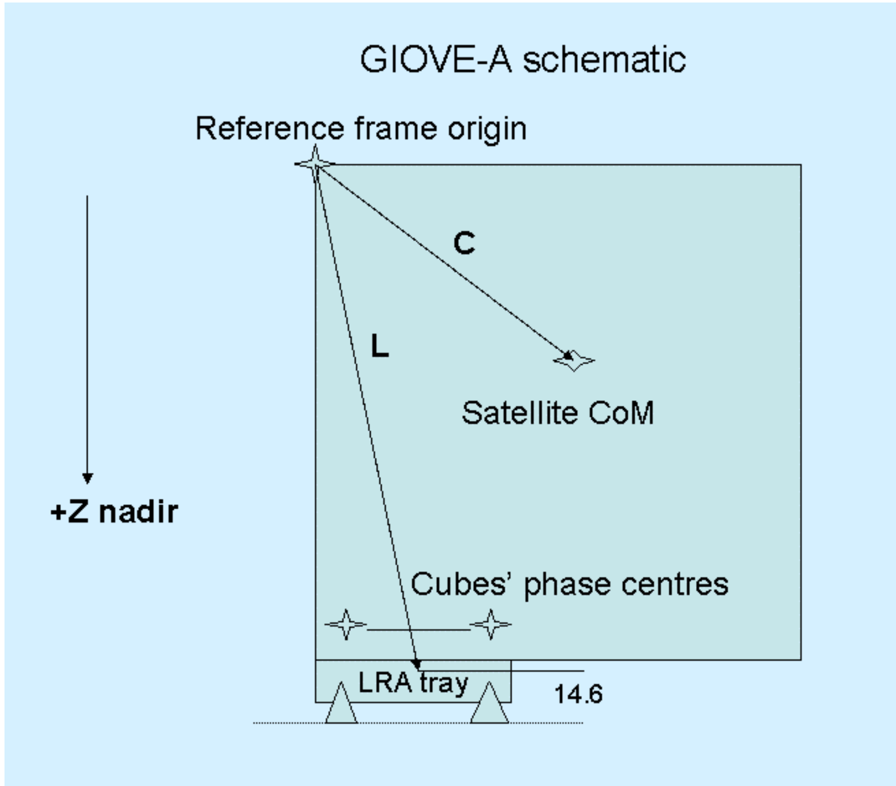
16. Whether or not the cubes are coated and with what material:

An example of the metric information (points 5-8 above) that should be supplied is given schematically below for the LRA on the GIOVE-A satellite. Given the positions and characteristics of the cubes within the LRA tray (points 8-12), it is possible to compute the location of the array phase centre. Then given the **C** and **L** vectors (points 5 and 7) it is straightforward to calculate the vector from the satellite's centre of mass (CoM) in a spacecraft-fixed frame to the LRA phase centre. Further analysis to derive the array far-field diffraction patterns will be possible using the information given in points 8-16.



A good example of a well-specified LRA is that prepared by GFZ for the CHAMP mission in the paper '*'The Retro-Reflector for the CHAMP Satellite: Final Design and Realization*', which is available on the ILRS website at http://ilrs.gsfc.nasa.gov/docs/rra_champ.pdf

The final and possibly most complex piece of information is a description (for an active satellite) of the satellite's attitude regime as a function of time, which must be supplied in some form by the operating agency. This algorithm will relate the spacecraft reference frame to, for example, an inertial frame such as J2000.

References.

Two reports, both by David Arnold, are of particular interest in the design and analysis of laser retro-reflector arrays.

Method of Calculating Retroreflector-array Transfer Functions, David A. Arnold, Smithsonian Astrophysical Observatory Special Report 382, 1979.

Retroreflector Array Transfer Functions, David A. Arnold, ILRS Signal Processing Working Group, 2002. Paper available at http://nercslr.nmt.ac.uk/sig/signature.html

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